

Vowel Length Change in LuGanda*

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This paper reviews the analysis of compensatory lengthening in LuGanda by Clements (1986) and reanalyses it in the framework of OT. First, the defects of Clements' analysis in CV-phonology are pointed out: inconsistent use of C and V slots in representing nasals and consonants, syllabification problems with word-initial nasal clusters and geminate consonants, and an extrinsic ordering of many rules in resolving vowel hiatus. These problems are shown to be eliminated by the interaction of faithfulness and markedness constraints. The first problem does not occur in our OT-based analysis at all. The second one is solved by the constraint ranking $M_{AX-C} \gg M_{AX-\mu}$, *COMP . Vowel hiatus contexts are also resolved by the constraint ranking. Especially, the directionality of vowel deletion is decided by constraints such as a contiguity constraint $I-CONTIG[X, ROOT]$ and a positional faithfulness constraint M_{AX-Wi} and by their position in the ranking. The former constraint is responsible for preserving the contiguity of a root and its immediately preceding segment, while the latter is for keeping word-initial segments, which are salient compared with their word-medial or word-final counterparts. Violability and strict domination of OT constraints are shown to be important in explaining the change in vowel length in LuGanda.

Key words: LuGanda, vowel lengthening and shortening, nasal clusters, geminates, OT, positional faithfulness constraint

1. Introduction

The goal of this study is to review the analysis of Clements (1986) of compensatory lengthening in LuGanda, a Bantu language of East Africa, and reanalyse it in the framework of Optimality Theory (Prince & Smolensky, 1993; McCarthy & Prince, 1993, 1995). The latter approach will

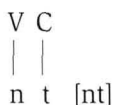
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be shown to provide a better way of explaining several phenomena related with vowel quantity change.

In the past 1980's, the theory of phonological representation was in full swing and there were two representations of weight: skeletal slot models (McCarthy, 1979; Clements & Keyser, 1983; Levin, 1983, 1985) and moraic models (Hyman, 1985; Hayes, 1989). For instance, in so-called CV phonology, which Clements adopts in his analysis, abstract and autonomous weight units represented with C's and V's in the CV tier are linked with segments in the segmental tier. The linkage types between the two tiers were shown to be responsible for the phonological behavior of marked segments such as contour segments, long or geminate segments, semi-vowels, and syllabic nasals.

Noticing the change in vowel length before nasal clusters and geminate consonants in LuGanda, Clements presents the following (1) as their underlying representations. He assigns a V slot to the first portion of nasal clusters and geminate consonants, based on the fact that LuGanda cannot have more than three moras in a syllable and on the assumption that only V slots can have mora.

(1) a. nasal cluster



b. geminate consonant



We are going to review the analysis of Clements and reanalyze the data from the viewpoint of Optimality Theory, showing that vowel lengthening and shortening in LuGanda result from the interaction of faithfulness and markedness constraints.

This study is organized as follows. In section 2, some defects of Clements' analysis are pointed out: inconsistent use of C and V slots in representing nasals and consonants, syllabification problems with word-initial nasal clusters and geminate consonants, and an extrinsic ordering of many rules in resolving vowel hiatus problems. Section 3, the main part of this study, reveals that the change in vowel quantity is due to an interaction of faithfulness and markedness constraints and that the three problems of Clements' are eliminated by the way the theory works. For instance, the ranking $M_{AX-C} \gg M_{AX-\mu}$, $*C_{OMP}$ deals with syllabification of word-initial nasal clusters and geminate consonants. And in combination with other

constraints, O_{NSET} and D_{EP} in the highest ranking take care of vowel hiatus and allow no insertion of consonants, doing the job of Twin Vowel Deletion and Nonhigh Vowel Deletion of rule-based CV-phonology. A proper ranking of constraints such as a bimaic constraint $[\mu\mu]_0$, $M_{\text{AX-C}}$, $C_{\text{ODA CONDITION}}$, $^*C_{\text{OMPELX}}$, and $M_{\text{AX-}\mu}$ deals with vowel lengthening in front of nasal clusters and vowel shortening in front of geminate consonants. Especially, $C_{\text{ODA CONDITION}}$ and $^*C_{\text{OMPELX}}$ are responsible for syllabification of nasal clusters and geminate consonants. Vowel hiatus contexts are also resolved by the ranking constraints. The directionality of vowel deletion is provided by considering a contiguity constraint $I\text{-}C_{\text{ONTIGUITY}}[V, \text{ROOT}]$ and a positional faithfulness constraint $M_{\text{AX-}W_i}$ and their position in the ranking. The former is responsible for preserving the contiguity of a root and its immediately preceding vowel, while the latter is for keeping word-initial segments, which are salient, compared with their word-medial or word-final counterparts. This study is one more example of showing the importance of violability and strict domination of constraints: constraints can be violated under duress of higher constraints. Summary is given in section 4.

2. Problems with Clements (1986)

2.1. V slots in Nasal Clusters and Geminate Consonants

The first problem with Clements' analysis lies in the underlying representation of nasal clusters and geminate consonants in (2). A set of data relevant to our study is given below. The dot in the surface form represents a syllable boundary.

(2) Vowel lengthening before nasal clusters

/ku + linda/ → [ku.lii.nda] 'to wait'

/mu + lenzi/ → [mu.lee.nzi] 'boy'

/mu + ntu/ → [muu.ntu] 'person'

/ba + ntu/ → [baa.ntu] 'people'

Vowels before a nasal followed by an obstruent get lengthened. Observing that a syllable can take at most two moras in LuGanda, which is called a bimoraic limit, Clements represents nasals in the underlying representation as follows:

(3) a. *muuntu* 'person'

C	V	-	V	C	V
m	u		n	t	u

b. *mbuzi* 'goat'

V	-	C	V	C	V
m		b	u	z	i

The *m* in (3a) is linked with a C slot and the *n* in (3a) and the *m* in (3b) are linked with a V slot. It is noticeable that there is no consistency in the linkage of [+nasal] segments with CV slots. When a nasal is located before a vowel in the segmental tier, it is linked with a C slot, while it is linked with a V slot when followed by a consonant in the segmental tier.

On the other hand, vowels get shortened before geminate consonants:

(4) Vowel shortening before geminate consonants

/ba + a + tta/ → [bat.ta] 'they killed'

/ba + a + ee + tta/ → [bet.ta] 'they killed themselves'

/ye + e + a + tta/ → [yat.ta] 'it is he that kills'

Due to a bimoraic limit, Clements assigns a V slot to the first portion of geminate consonants and a C slot to their second portion to derive a short vowel before geminate consonants (Clements, 1986, p. 58). This is because Clements assumes that only a V slot has a mora, which is based on the observation of Cole (1967 p. 13): geminate consonants are heterosyllabic and their first mora is tonally and morphologically equivalent to the final mora of any other long syllable.

(5) a. *ttabi* 'branch'

V	C	V	C	V
∨				
t		a	b	i

b. *atta* 'he kills'

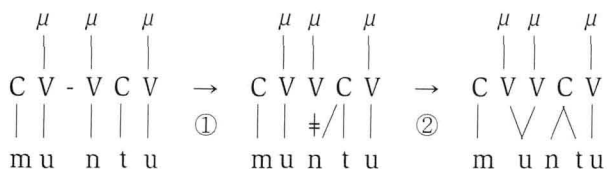
V	V	C	V
	∨		
a		t	a

Both nasal clusters and geminate consonants have a V slot followed by a C slot in their underlying representation. That is, the nasal element in the nasal clusters such as [nt] and [mb] in (3a, b) and the first portion of geminate consonants [tt] in (5) are assumed to have a V slot.

Although Clements does not mention what to do with syllabification, he states that at most one C slot can occur in the onset position (Clements

1986, p. 46).¹⁾ Then, the question is how to deal with word initial geminate consonants or nasal clusters in syllabification. Let us look at the derivation of *muuntu* 'person,' for example. Clements does not specify the tier of mora. However, given his assumption that only a V slot can have a mora, the derivation of *muuntu* would be as follows:

(6) /muntu/ → [muuntu] 'person'

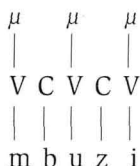


① Prenasalization ② Linking Convention²⁾

Prenasalization delinks the linkage between [n] and its V slot and reassociates the [n] with the following C slot occupied by [t], leading to a contour segment [nt]. Then Linking Convention links the vacant V slot, originally taken by [n], with the preceding vowel [u], which becomes long with two V slots.

In addition, Clements asserts that a word-initial nasal preceding an obstruent has one mora (Clements, 1986 p. 44). However, Prenasalization cannot apply to it, since the sequence of VC in word-initial position does not meet the structural description VVC of the process (See footnote 2 for its structural description). The word *mbuzi* should be both trimoraic and trisyllabic with [m] being a syllabic nasal.

(7) mbuzi 'goat'



1) Clements posits $C_0^1V^*$ as a syllable template in the CV tier, where * stands for a potential sequence. However, the number of V slots in the template is limited to two since a syllable cannot hold more than three moras in LuGanda.

2) Clements posits Prenasalization and Linking Convention as follows:

① Prenasalization

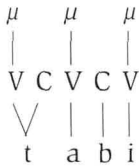
V V C
| | |
+ . .
[+nas]

② Linking Convention

V'
|
:
[+cons] (V' stands for a vacant V slot.)

Our next question is what will happen to geminate consonants. Since the first portion of a geminate consonant counts as one mora, the representation in (5) would be as follows:

(8) a. *ttabi* 'branch'



b. *atta* 'he kills'



In (8b) the first syllable [at] has two moras consisting of two V's, while the second one [ta] has one mora with only one V in the CV tier.

The question is whether the first V slot in *ttabi* (8a) constitutes a separate syllable or not. In LuGanda can an obstruent be a syllabic consonant, like [m] in (7), a word-initial nasal in front of an obstruent? In the latter, the nasal [m] is higher in sonority than its neighboring segment [b] and it can constitute a separate syllable. However, [t] in *ttabi* is not more sonorous than its neighboring segment [a] and cannot be a syllabic consonant even when it has a V slot. Then, what to do with the first mora of (8a)? Is *ttabi* bisyllabic or trisyllabic? If it is bisyllabic, the first mora should be deleted or linked with a syllable node consisting of [ta] somehow. If it is trisyllabic, the first syllable should consist of V slot, which is linked with [+consonantal, -sonorant] segment.

2.2. Vowel Hiatus Resolution

The second problem with Clements' analysis is related with the way vowel hiatus is resolved. Let us look at the derivation of *betta* in (4), where a long vowel and sequences of identical and unidentical vowels are involved in its underlying representation:³⁾

3) The relevant rules from Clements (1986) are as follows (② is given in footnote 2):

③ Twin Vowel Deletion ④ Nonhigh Vowel Deletion ⑤ V-trimming

$$\begin{array}{cc}
 V & V \\
 \# & | \\
 [aF] & [aF]
 \end{array}$$

$$\begin{array}{cc}
 V & V \\
 \# & | \\
 [-high] & [-cons]
 \end{array}$$

$$\begin{array}{c}
 V_Q \rightarrow \emptyset / _ V V \\
 \text{(where Q is a maximum} \\
 \text{sequence of V's)}
 \end{array}$$

(9) /ba + a + ee + tta/ → [bet.ta] 'they killed themselves'

C	V	-	V	-	V	-	V	C	V	→	C	V	V	V	V	C	V	→
					∨		∨			③②		∨		∨	∨		④	
b	a		a		e		t	a			b	a		e		t	a	

C	V	V	V	V	C	V	→	C	V	V	V	V	C	V	→
			∨	∨			②		∖		/	/	∨		⑤
b			e		t	a		b		e			t	a	

C	V	V	C	V
		∨		
b	e		t	a

② Linking Convention⁴⁾

③ Twin Vowel Deletion

④ Nonhigh Vowel Deletion ⑤ V-trimming

A sequence of identical vowels [a] + [a] is a violation of OCP and it is united into a long vowel [a:] via Twin Vowel Deletion followed by Linking Convention. Next, this [a:] is deleted by Nonhigh Vowel Deletion, which disconnects the linkage between a nonhigh vowel [a:] and its V slots when followed by another vowel. The vacant V slots are filled in with the following vowel [e] by Linking Convention again. At the final stage of derivation V-trimming deletes all V slots except for the last two, each of which is taken by [e] and [t]. The principal role of V-trimming is to keep a bimoraic limit. The surface form *betta* is bisyllabic but trimoraic with three V slots. The first portion of geminate [tt] comprises one mora of the first syllable.

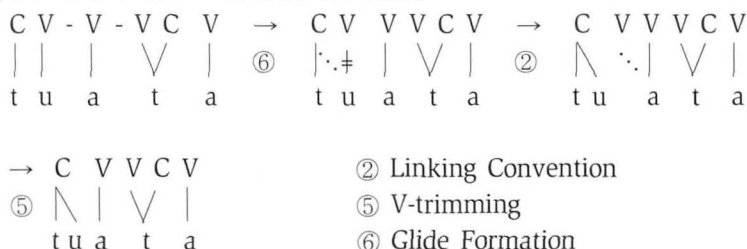
Another way of resolving vowel hiatus is Glide Formation.⁵⁾ The following example has a sequence of two vowels, where the first member is high and becomes a semivowel:

4) Prenasalization ① does not apply here due to a lack of a proper environment.

5) In Glide Formation the linkage between a high vowel and its V slot is delinked and the vowel reassociates with the preceding C slot:

C	V	V
∴	+	
[+high] [-high]		

(10) /tu + a + tta/ → twatta 'we killed'



Whenever high vowels /i/ or /u/ come before another vowel, they become semivowels [y] or [w]. Via Glide Formation vowel [u] associates to a C slot and is realized as semivowel [w]. The vacant V slot is filled in with the following vowel [a] via Linking Convention. At this stage there is a sequence of three V slots and this undergoes V-trimming, deleting the first V slot and leaving the second and third. The remaining two V's are taken by vowel [a] and the first portion of geminate [tt]. The output [twat.ta] is bisyllabic but trimoraic.

According to the analysis of Clements, six rules are needed in describing the change in vowel quantity. The relevant contexts are provided from two sources: one is nasal clusters and geminate consonants, and the other is vowel hiatus contexts. Pertinent to the first context is an inconsistency problem in representing the nasal portion of nasal clusters and the first portion of geminate consonants in their underlying representation, which is linked with a V slot due to mora assignment. There ensues an indecision problem in syllabification of word-initial nasal clusters and geminate consonants. The second context leads to the necessity of employing a little too many rules in a certain order in derivation.

3. OT-Based Approach

The analysis in this section is couched in OT. Following Clements, both the nasal portion of nasal clusters and the first half of geminates are assumed to have a mora in the underlying representation. Some preliminary constraints are given in (11), which is to be supplemented as more data are considered.

- (11) a. $[\mu\mu]_0$: A syllable can have two moras at most.
 b. M_{AX-C} : The input consonant has a correspondent in the output.
 c. $M_{AX-\mu}$: The input mora has a correspondent in the output.
 d. $CODA_CONDITION$: Coda consonants are not allowed except when they are a part of geminate consonants.
 e. $*C_{OMP}$: Complex onsets or codas are not allowed.

Constraint $[\mu\mu]_0$ is a restatement of a bimoraic limit, while M_{AX-C} prevents the deletion of the input consonants. In combination with other constraints, this is mainly responsible for retaining the first portion of nasal clusters and geminate consonants, leading to vowel lengthening and shortening. Constraint $M_{AX-\mu}$ is concerned with the maintenance of the input mora in the output. Constraint $CODA_CONDITION$ allows only a part of geminate consonants in the coda, while $*C_{OMP}$ restricts the size of syllable margins to a single consonant. Constraints $[\mu\mu]_0$, M_{AX-C} , and $CODA_CONDITION$ are never violated and thus placed in the highest rank. Both $M_{AX-\mu}$ and $*C_{OMP}$ rank below them, while the ranking between the two is undetermined.

3.1. Syllabification of Nasal Clusters and Geminate Consonants

As far as nasal clusters are concerned, the followings can be predicted. Nasal clusters in word-medial position lead to lengthening of their preceding vowels, while those in word-initial position do not. This is because of $M_{AX-\mu}$ and also because M_{AX-C} prevents the deletion of the nasal portion, while $CODA_CONDITION$ makes it impossible for it to become a coda. Thus, the nasal portion has no other choice but to become a part of complex onset, leaving its mora to the preceding vowel in word-medial position while losing its moraicity in word-initial position.⁶⁾

Let us look at nasal clusters in word-medial position first to see whether the prediction is right or not.

6) Onset consonants do not have mora, while coda consonants do via a weight-by-position (Hayes 1989).

(12) /mu + ntu/ → [muu.ntu] 'person'

mu+n _μ tu	[μμ] _σ	M _{AX} -C	C _{ODA} CON	M _{AX} -μ	*C _{OMP}
a. mun.tu			*!		
☞ b. muu.ntu					*
c. mu.ntu				*!	*
d. muun.tu	*!		*		
e. muu.tu		*!			
f. mu.tu		*!		*	

Candidates (a) and (d) have a coda [n], which is against C_{ODA} CONDITION. In addition, candidate (d) has three moras in the first syllable, violating a bimoraic limit [μμ]_σ. Candidate (c) violates both M_{AX}-μ and *C_{OMPLEX}, with its onset [nt]. Candidates (e) and (f) violate M_{AX}-C, with no output correspondent of the input consonant /n/. M_{AX}-μ is also violated in candidate (f), since it has two moras instead of three. Candidate (b) is the optimal output, even though its onset [nt] violates *C_{OMPLEX}, the lowest in the rank.

Vowel lengthening before nasal clusters results from the constraint ranking: [μμ]_σ, M_{AX}-C, C_{ODA} CONDITION ≫ M_{AX}-μ, *C_{OMP}.

A little different situation can result from geminate consonants in word-medial position such as *atta* 'he kills.' Due to the ranking [μμ]_σ ≫ M_{AX}-μ, the first half of geminate consonants does not delete. Instead, it becomes the coda of the preceding syllable. When the preceding syllable has a long vowel, vowel shortening takes place. There is no change of vowel length, when the vowel of the preceding syllable is short. The case of vowel shortening before geminate consonants will be seen later in (19a): /ba + a + ee + tta/ → [bet.ta] 'they killed themselves.' Let us consider the second case, first.

(13) /atta/ → [at.ta] 'he kills'

at _μ ta	[μμ] _σ	M _{AX} -C	C _{ODA} CON	M _{AX} -μ	*C _{OMP}
a. a.ta		*!		*	
☞ b. at.ta					
c. a.tta				*!	*
d. att.a	*!		*		*

Candidate (a) has only one portion of geminate [tt], violating M_{AX}-C and

$M_{AX-\mu}$. Candidate (c) with its onset [tt] violates $M_{AX-\mu}$ and $^*C_{OMP}$, since onset consonants have no mora. Candidate (d) with [tt] as its coda violates $[\mu\mu]_0$, CODA CONDITION, and $^*C_{OMP}$. As a result, the optimal output is [at.ta], which happens to violate no constraints at all.

Next is the case where nasal clusters and geminate consonants are at the beginning of a word.⁷⁾

(14) /mbuzi/ → [mbu.zi] 'goat', /ttabi/ → [tta.bi] 'branch'

m ₀ buzi	M_{AX-C}	$M_{AX-\mu}$	$^*C_{OMP}$
☞ a. mbu.zi		*	*
b. bu.zi	*!	*	
t ₀ tabi	M_{AX-C}	$M_{AX-\mu}$	$^*C_{OMP}$
☞ a. tta.bi		*	*
b. ta.bi	*!	*	

With [mb] or [tt] for their onset, candidates (a) violate both $M_{AX-\mu}$ and C_{OMP} . However, they fare better than candidates (b), where the higher constraint M_{AX-C} is violated, with the deletion of the nasal and first portion of complex consonants.⁸⁾

The ranking $M_{AX-C} \gg M_{AX-\mu}$, $^*C_{OMP}$ eliminates the problem of syllabification of word-initial nasal clusters and geminate consonants in the previous section. In order to respect the higher constraint M_{AX-C} , the lower constraints $M_{AX-\mu}$ and $^*C_{OMP}$ can be violated. That is, since no input consonants can be deleted, the first portion of nasal clusters and geminates has to be syllabified. In word-initial position, it has to be a part of onset, losing its moraicity and thus violating the relevant constraints $M_{AX-\mu}$ and $^*C_{OMP}$.

As can be seen from the above, syllabification of nasal clusters and geminate consonants follows from the constraint hierarchy $[\mu\mu]_0$, M_{AX-C} , CODA CONDITION $\gg M_{AX-\mu}$, $^*C_{OMP}$. Their syllabification in word-initial position presents no problem of indecision and vowel lengthening before nasal clusters results also from the constraint ranking. Vowel shortening before geminate consonants will be considered next.

7) Constraint $[\mu\mu]_0$ is not included in tableau (14), since word-initial nasal clusters and geminate consonants are irrelevant to the size of syllable in the output.

8) We may think that the output forms [m.bu.si] and [t.ta.bi] are optimal since they violate no constraints at all. However, only vowels take the position of syllable nucleus in LuGanda. We regard the relevant constraint as one of the highest constraints and decide not to include it in our discussion.

3.2. Syllabification in Vowel Hiatus Contexts

Now we are going to see how vowel hiatus is resolved. In addition, it will be shown that vowel shortening in front of geminate consonants results from the same constraint ranking, although it is to be supplemented.

Let us go to the cases of vowel hiatus in (15), where a verb stem /-kuba/ 'strike' is involved. In section 2, Twin Vowel Deletion deals with a sequence of identical vowels in (15c) and (15d), while Nonhigh Vowel Deletion takes care of that of unidentical vowels in (15b) and (15d).

- (15) a. /ba + kuba/ → [ba.ku.ba] 'they strike'
 b. /ba + ee + kuba/ → [bee.ku.ba] 'they strike themselves'
 c. /ba + a + kuba/ → [baa.ku.ba] 'they struck'
 d. /ba + a + ee + kuba/ → [bee.ku.ba] 'they struck themselves'

Several things can be noticed from the above data. First, a sequence of vowels, either unidentical or identical, is not allowed: the output form of (15b), (15c), and (15d) is not *[ba.ee.ku.ba], *[ba.a.ku.ba], or *[ba.a.ee.ku.ba], respectively. Second, a vowel adjacent to the root (stem minus final vowel) survives in the context of vowel hiatus. Thus, the long vowel /ee/ in (15b, d) and the second /a/ in (15c) remain in the surface, while those preceding them get deleted. Third, no insertion of any onset consonant is allowed to resolve vowel hiatus, as in *[ba.Ca.ku.ba], for instance. Fourth, a morpheme may not be realized in the output under the pressure from the higher constraints as in (15d), where the past tense morpheme /a/ is not realized.

The following constraints are posited in the light of these observations.

- (16) a. $ONSET$: A syllable should have an onset consonant.
 b. DEP : Every segment of the output has a correspondent in the input.
 c. $MORPHEME\ REALIZATION$: A morpheme should be realized phonetically in the output.⁹⁾
 d. $I-CONTIG[X, ROOT]$: A root and its preceding segment X of the input standing in correspondence form a contiguous string.¹⁰⁾

9) This constraint is originated from Samek-Lodovici (1993), which is cited by Boroff (2003, p. 20): "Every morpheme in the input should have a unique phonetic realization in the output."

10) Since linearity constraints are mainly for preventing metathesis, contiguity constraints are

The principal role of O_{NSET} is to prevent vowel hiatus. However, an insertion of onset consonants cannot be the solution because of DEP . It will be seen shortly that the high ranking of the two constraints O_{NSET} and DEP forces the violation of the lower constraints. $MORPHEME\ REALIZATION$ is different from M_{AX} in that it can prevent the deletion of a monosegmental morpheme. The deletion of a morpheme consisting of a single segment violates both $MORPHEME\ REALIZATION$ and M_{AX} . However, the ranking $MORPHEME\ REALIZATION \gg M_{\text{AX}}$ penalizes more severely the deletion of a segment in a monosegmental morpheme than that in a morpheme composed of several segments. $I\text{-}CONTIG[X, \text{ROOT}]$ makes sure that the contiguity of a root and its immediately preceding segment in the input is maintained in the output. As a consequence, a segment immediately preceding a root is not skipped in the output.

Let us take a look at the situation of (15b), first.

(17) /ba + ee + kuba/ → [bee.ku.ba] ‘they strike themselves’

ba+ee+kuba	O_{NSET}	DEP	$MORREAL$	$M_{\text{AX-}\mu}$	$I\text{-}CONTIG[X, R]$
a. ba.ee.ku.ba	*!				
b. ba.Cee.ku.ba		*!			
c. ba.e.ku.ba	*!			*	
☞ d. bee.ku.ba				*	
e. baa.ku.ba			*!	*	*

Candidates (a, b, c) are ruled out, violating either O_{NSET} or DEP . Candidate (e) has no realization of morpheme /ee/ ‘themselves,’ which is immediately before root /-kub/, and thus violates $MORPHEME\ REALIZATION$ and $M_{\text{AX-}\mu}$ as well as $I\text{-}CONTIGUITY[X, \text{ROOT}]$. The optimal output is candidate (d), which violates the lowest constraint $M_{\text{AX-}\mu}$ with the deletion of vowel [a] of morpheme /ba/ ‘they.’ However, it does not violate $MORPHEME\ REALIZATION$, since the morpheme has its phonetic realization in the output as [b]. It has no violation of $I\text{-}CONTIGUITY[X, \text{ROOT}]$, either.

We are going to skip (15c) and go to (15d), since the two have the same sequence of identical vowels. Candidates with inserted consonants will not be included in the following tableaux, unless necessary, since the situation

adopted here for the purpose of preventing “skipping.” See McCarthy and Prince (1995, p. 12-13) for more details.

of (17b) is thought to be enough to see the effect of D_{EP} on selecting the optimal output.

(18) /ba + a + ee + kuba/ → [bee.ku.ba] ‘they struck themselves’

ba ₁ +a ₂ +ee+kuba	ONSET	MORREAL	M _{AX} -μ	I-CONTIG[X, R]
a. ba ₁ a ₂ .ee.ku.ba	**!			
b. ba ₁ a ₁ .ku.ba		*!*	**	*
☞ c. bee.ku.ba		*	**	
d. ba ₂ .ee.ku.ba	*!		*	
e. ba ₂ a ₂ .ee.ku.ba	*!			

A sequence of either identical vowels [a] + [a] or unidentical vowels [a] + [e] violates O_{NSET} , which rules out candidates (a), (d), and (e). Candidate (b) has no output correspondent of /a₂/ and a long vowel /ee/, making two violations of both $M_{\text{ORPHEME REALIZATION}}$ and $M_{\text{AX}}-\mu$ on the one hand and one violation of violating $I\text{-CONTIGUITY}[X, R]$ on the other hand. Candidate (c) becomes optimal since it has one less violation of $M_{\text{ORPHEME REALIZATION}}$. The strictness of constraint domination makes any violation of the lower constraints such as $M_{\text{AX}}-\mu$ and $I\text{-CONTIGUITY}[X, R]$ irrelevant to the selection of candidate (c) as the optimal output.¹¹⁾

Next is a vowel hiatus context involving geminate consonants, partly repeated from (4).

- (19) a. /ba + a + ee + tta/ → [bet.ta] ‘they killed themselves’
 b. /tu + a + tta/ → [twat.ta] ‘we killed’
 c. /ye + e a + tta/ → [yat.ta] ‘it is he that kills’

Four things can be noticed from (19). First, a long vowel /ee/ becomes short in front of geminate consonants. Second, there is no shortening of geminate consonants, which survive as each portion takes the coda and onset position of the adjacent syllables; $M_{\text{AX}}\text{-C}$ in (11b) keeps them intact.

11) More candidates can be compared, where corresponding output vowels are different from those of candidate (b) and (e). The optimal output is still (18c), as can be seen below.

ba ₁ +a ₂ +ee+kuba	ONSET	MORREAL	M _{AX} -μ	I-CONTIG[X, R]
f. ba ₂ a ₂ .ku.ba		*	**	*
g. ba ₁ a ₂ .ku.ba		*	**	*

Third, when the first member of a sequence of two vowels is high, it becomes a semivowel: /u/ + /a/ → [wa] or /i/ + /a/ → [ya]. Finally, when two monosegmental morphemes abut across a word boundary, a word initial monosegmental morpheme survives. In (19c), there is a word boundary between /ye + e/ and /a + tta/ and two monosegmental morphemes /e/ and /a/ are adjacent. In order to respect *ONSET*, only one of the two should remain and a word-initial segment /a/ survives.

The first two facts can be dealt with by constraints *M_{AX}-C*, *I-CONTIGUITY*[X, *ROOT*], and *CODA CONDITION*. For the third fact in (19b), the following constraint is in need:

- (20) *M_{AX}[+high]*: A segment with the [+high] feature in the input has a correspondent in the output.

Since high vowels are never totally deleted in the contexts of vowel hiatus and become semivowels, *M_{AX}[+high]* is among the highest constraints in the rank.

For the fourth fact in (19c), where a word boundary is involved in vowel hiatus, another constraint is necessary to maintain a word-initial segment.¹²⁾

- (21) *M_{AX}-W_i*: A word-initial segment in the input has a correspondent in the output.

This is one of positional faithfulness constraints, whereby segments in the

12) The survival of word-initial segments in vowel hiatus contexts across a word boundary is confirmed in the following examples (Clement, 1987 p. 50 & p. 55):

/na	o + mu + ntu/	→ [noo.mu.untu]	'and/with the person'	
/e + ki + kopo	e + ki + o/	→ [e.ki.ko.pee.kyo]	'that cup'	
/a + tem + e	o + mu + ti/	→ [a.te.moo.mu.ti]	'let him cut the tree'	
/o + mu + tue	o + gu + e	o + yi + o	o + mu + kazi/	→ [o.mu.twoo.gwoo.yoo.mu.kazi]
head	of	that	woman	'that woman's head'

The second and third examples violate *ONSET*. Candidates with an inserted onset such as *[Ce.ki.ko.pee.kyo] might be optimal for the second example, since a violation of either *DEP* or *ONSET* costs equally. However, constraint *ALIGN-L*: [*Prefix* = [*PrWd*] ranking above both *DEP* and *ONSET* selects a candidate with no onset inserted at the beginning of a prosodic word as the optimal output.

In passing, there is no vowel lengthening word-finally in the second example, even after a high vowel /i/ becomes [y]. In LuGanda, word-final long vowels are not allowed and thus *M_{AX}-u* is violated because of the higher constraint *V]_w. Both *ALIGN-L*: [*Prefix* = [*PrWd*] and *V]_w will not be included in our discussion, since their exclusion is not critical in our discussion.

positions of salience tend to remain intact: for example, those in syllable-, root-, morpheme-, and word-initial positions are stronger and more likely to survive and retain their features than their counterparts in non-initial positions.

Equipped with (20) and (21) as well as with (11) and (16), the situation of (19a) is as follows.

(22) /ba + a + ee + tta/ → [bet.ta] ‘they killed themselves’

ba ₁ +a ₂ +ee+t _μ ta	M _{AX} -C	ONSET	MORREAL	M _{AX} -μ	*C _{OMP}	I-CONTIG[X, R]
a. ba ₁ a ₂ ee.tta		*!		*	*	
b. ba ₂ a ₂ ee.tta		*!		*	*	
c. bee.tta			*	***	*!	
d. ba ₂ t.ta			*	***		*!
☐ e. bet.ta			*	***		
f. bee.ta	*!		*	***		

A violation of M_{AX}-C rules out candidate (f), with only one portion of geminate consonants realized. The sequence of vowels [a] + [e] violates ONSET, which eliminates candidates (a) and (b). The onset [tt] in (a), (b), and (c) violates *C_{OMP}. Candidate (c) has no realization of the past tense morpheme /a₂/, violating MORPHEME REALIZATION and M_{AX}-μ. As far as MORPHEME REALIZATION and M_{AX}-μ are concerned, candidates (d) and (e) are equal. However, candidate (d) has no realization of a long vowel /ee/ ‘themselves,’ violating I-CONTIGUITY[X, ROOT] to boot, which is not in the case of candidate (e). Thus, the output [bet.ta] becomes optimal.

Next is the case of a vowel hiatus context with a high vowel as in (19b).

(23) /tu + a + tta/ → [twat.ta] ‘we killed’

tu+a+t _μ ta	ONSET	M _{AX} [+hi]	MORREAL	M _{AX} -μ	*C _{OMP}	I-CONTIG[X, R]
a. tu.at.ta	*!			*	*	
b. tu.at.ta	*!					
☐ c. twat.ta				*		
d. tut.ta			*!	*		*!
e. tat.ta		*!		*		

Candidates (a) and (b) have a vowel hiatus context, violating O_{NSET} and candidate (e) has no correspondent of a high vowel /u/, violating $M_{\text{AX}}[+\text{high}]$. Thus the three candidates are out of consideration. Although candidate (d) respects both O_{NSET} and $M_{\text{AX}}[+\text{high}]$, it has no realization of the past tense morpheme /a/, violating $M_{\text{ORPHEME}} \text{ REALIZATION}$ and $I\text{-CONTIGUITY}[X, \text{ROOT}]$ as well as $M_{\text{AX}}\mu$. Candidate (c) is the optimal output with a loss of one mora only.

Finally, the following tableau is the situation of (19c), where vowel hiatus takes place between words.

(24) /ye + e a + tta/ → [yat.ta] 'it's he that kills'

ye ₁ +e ₂ a+t ₁ ta	O_{NSET}	$M_{\text{AX}}\text{-}W_i$	M_{ORREAL}	$M_{\text{AX}}\mu$
a. ye ₁ e ₂ at.ta	**!			
b. ye ₁ e ₂ at.ta	*!			
c. ye ₁ t.ta		*!	**	**
d. ye ₂ t.ta		*!	*	**
e. yat.ta			*	**

Since $M_{\text{AX}}[+\text{high}]$ is irrelevant and $^*_{\text{COMP}}$ does not make any difference in the selection of the optimal output, they are not included in the above tableau. Candidates (a) and (b) are eliminated because of vowel hiatus. Candidate (c) fares worse than candidate (d) due to one more violation of $M_{\text{ORPHEME}} \text{ REALIZATION}$, since two morphemes /e₂/ and /a/ have no output correspondents. Our concern is with candidates (d) and (e). They are equal as far as constraints $M_{\text{ORPHEME}} \text{ REALIZATION}$ and $M_{\text{AX}}\mu$ are concerned. Candidate (e) is optimal with a word-initial segment /a/ being realized as [a], while there is no output correspondent of /a/ in candidate (d), violating $M_{\text{AX}}\text{-}W_i$.¹³

The constraint hierarchy suggested so far is as follows, although some rankings are still undetermined. With more data available, the constraint ranking could be more specific. Unfortunately, this is all we can get from the data from Clements (1986) regarding vowel length change in LuGanda.

13) Instead of $M_{\text{AX}}\text{-}W_i$, constraint $I\text{-CONTIG}[X, \text{ROOT}]$ can do the same job of selecting candidate (e) rather than (d). However, for those data in footnote 12), we are going to use $M_{\text{AX}}\text{-}W_i$, when the word boundary is involved in vowel hiatus contexts.

- (25) $[\mu\mu]_b, \text{ONSET}, \text{MAX-C}, \text{DEP}, \text{CODA CONDITION}, \text{MAX-[+high]} \gg \text{MAX-W}_i,$
 $\text{MORPHEME REALIZATION} \gg \text{MAX-}\mu, {}^*\text{COMP}, \text{I-CONTIGUITY}[X, \text{Root}]$

4. Summary

The three problems of Clements' analysis of LuGanda data related with vowel quantity change have been pointed out in this study. The first problem is the inconsistency in representing nasal clusters and geminate consonants, the first portion of which is represented as a V slot. On the other hand, nasals before vowels and singleton consonants are represented as a C slot. Thus, the representation of segments depend on their linear position in a word.

The second one is impossibility and indecision related with syllabification of nasal clusters and geminate consonants in word-initial position. Prenasalization, which is responsible for compensatory lengthening before nasal clusters, has no way of dealing with word-initial nasal clusters, since the structural description of the rule itself is not fit for them. As for word-initial geminate consonants, the analysis along the line of Clements is indeterminate in syllabifying the first timing slot V in *ttabi* 'branch' of (8a). Since the syllable template of LuGanda allows only one timing slot in the onset, there is no way for the first V slot linked with [t] to get affiliated with any syllable position. Even when it is regarded as a trisyllabic word like [t.ta.bi], the first segment [t] should be the nucleus of the first syllable, which is not allowed in LuGanda.

The third one is related with the way vowel hiatus is resolved in the analysis of Clements: use of a little too many rules in a fixed order.

On the other hand, an OT-based analysis in section 3 can get rid of the above three problems by resorting to the constraint ranking in (25). As for syllabification of word-initial nasal clusters and geminate consonants such as [mbu.zu] and [tta.bi], the ranking $\text{MAX-C} \gg \text{MAX-}\mu, {}^*\text{COMP}$ is responsible for the retention of all consonants as well as the loss of moraicity of the first portion [m] and [t]. Compensatory lengthening before nasal clusters and vowel shortening before geminate consonants are by-products of the ranking $[\mu\mu]_b, \text{MAX-C}, \text{CODA CONDITION} \gg \text{MAX-}\mu, {}^*\text{COMP}$.

With regard to vowel hiatus resolution, ONSET alone cannot decide which vowel deletes. For example, a sequence of $/(\text{C})\text{V}_1 + \text{V}_2 + \text{CV}/$ can become either $[(\text{C})\text{V}_1\text{CV}]$ or $[(\text{C})\text{V}_2\text{CV}]$ in the output, since both involve the loss of

exactly one vowel segment. The directionality of vowel deletion cannot be directly incorporated into constraints as it can in rule-based phonology with rules like either $V \rightarrow \emptyset / _ V$ or $V \rightarrow \emptyset / V _$. In order to respect the spirit of OT and reflect the effect of V_1 deletion in the output, an indirect expression of directionality should be found out. To make sure that a vowel immediately preceding a root survives in vowel hiatus context, a contiguity constraint $I\text{-CONTIGUITY}[X, \text{ROOT}]$ is adopted. In addition, a positional faithfulness constraint $M_{AX}\text{-}W_i$ takes care of resolving vowel hiatus across a word boundary. Both constraints ensure the survival of the second vowel in vowel hiatus contexts. These constraints, when in combination with other constraints in the ranking, reflects indirectly the directional effects of conventional phonological rules.

Violability and strict domination of constraints are shown to play important roles in this study, confirming principal properties of OT constraints. For example, both candidates (b) and (c) in tableau (23) have just one violation mark. However, the satisfaction of the higher constraint O_{NSET} is the more important than that of the lower constraint $M_{AX}\text{-}\mu$. Thus, the optimal output (23c) violates $M_{AX}\text{-}\mu$ in order to respect the higher constraint O_{NSET} .

Considering what has been presented so far in this study, the adoption of the framework of OT can be said to offer a better solution to vowel lengthening and shortening phenomena in LuGanda.

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